FIELD EMISSION PEAKING SWITCH STUDIES

J. M. Gahl†, J. L. Borovina†, W. M. White†, and D. W. Scholfield‡
† Department of Electrical & Computer Engineering, University of New Mexico, Albuquerque, NM
‡ Air Force Research Laboratory, Directed Energy Directorate, Kirtland Air Force Base, NM

Abstract

Recent experiments by Shimomura, et al., [1] investigated intense electromagnetic transient breakdown in low-pressure gasses. This work strongly suggests that vacuum gap switches could have great utility as peaking switches for extremely high voltage pulsers in the subnanosecond regime. This paper describes the results of field emission peaking switch studies conducted at the Air Force Research Laboratory with the H-2 pulser. The pulser is capable of delivering 300 kV to a load with a 250-ps risetime. The effects of electrode material and switch geometry on switching performance will be discussed.

I. INTRODUCTION

In work describing the electrical breakdown of low pressure gasses on the subnanosecond time scale, Shimomura, et al., [1] found that since the probability of electrons existing in the discharge region during the application of electric field is extremely low, electric field emission supplies virtually all initial electrons in this type of discharge. Scholfield, et al., [2] found a Paschen minimum in low-pressure nitrogen suggesting that conventional breakdown was unlikely below the pressure time product of one torr nanosecond.

These papers suggest that a vacuum gap should be able to hold off extremely high voltage in the subnanosecond time scale until field emission allows conduction of electrons and the passage of a sharpened pulse. In this time scale, a traditional vacuum gap discharge involving electrode material is not possible. Consequently, significant performance degradation was not observed in the vacuum gap even after repeated pulsing.

This paper describes the experimental results of pulse sharpening utilizing a vacuum gap of varied gap separation. The gap was driven by a Hindenberg series, hydrogen switched pulser at the Air Force Research Laboratory. An obvious motivation for this work is to investigate the feasibility of replacing high-pressure hydrogen peaking switches with vacuum gaps.

II. EXPERIMENTAL APPARATUS

The experiment was driven by the H-2 pulser, one of the Hindenberg series of pulsers at the Air Force Research Laboratory (Figure 1). Pulses are generated by a transformer with an extremely short pulse forming line above a peaking-gap switch. A capacitor bank drives the primary of the transformer through a self-breakdown gap. After the transformer charges the pulse forming line, the high-pressure peaking gap breaks, sending a pulse down a transmission line to the experimental vacuum peaking switch. Fast electric field sensors detect the pulse in the oil filled transmission line inbound to the experimental vacuum peaking switch, as well as the resulting transmitted pulse in an similar transmission line section terminated by a water load. The H-2 is capable of delivering a typical pulse of 300 kV to a matched 42-ohm load with a risetime as fast as 250 ps.

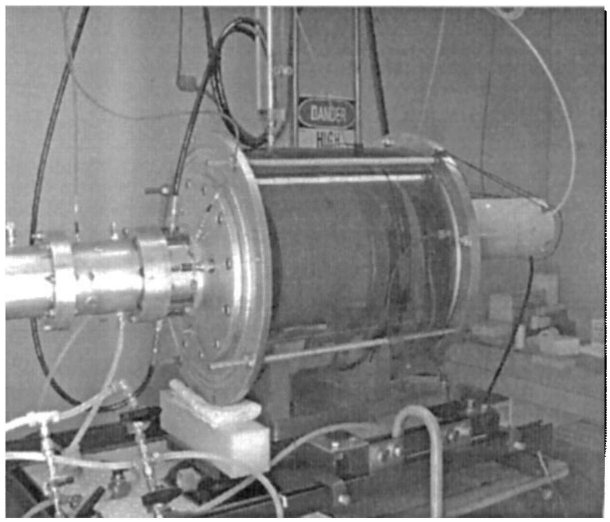

Figure 1. The H-2 pulser. The transformer is placed in the oil-filled container to the right, while the high-pressure hydrogen peaking switch, immediately to the left of the transformer assembly, is enclosed in its housing.

A schematic and photograph of the experimental vacuum peaking switch is shown in Figure 2. Annular aluminum electrodes were place directly on the center conductors of the oil filled transmission lines. Lexan insulated the electrodes and made the oil/vacuum boundary. A threaded insulating rod was placed between the two electrodes to facilitate precise separation and alignment. Data were collected for gap separations of 1.27 mm, 2.54 mm, and 5.08 mm. Electrodes were cleaned when the gap separation was changed, typically after hundreds of shots.

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14. ABSTRACT
Recent experiments by Shimomura, et al., [I] investigated intense electromagnetic transient breakdown in low-pressure gasses, This work strongly suggests that vacuum gap switches could have great utility as peaking switches for extremely high voltage pulsers in the subnanosecond regime. This paper describes the results of field emission peaking switch studies conducted at the Air Force Research Laboratory with the H-2 pulser. The pulser is capable of delivering 300 kV to a load with a 250-ps risetime. The effects of electrode material and switch geometry on switching performance will be discussed.

15. SUBJECT TERMS

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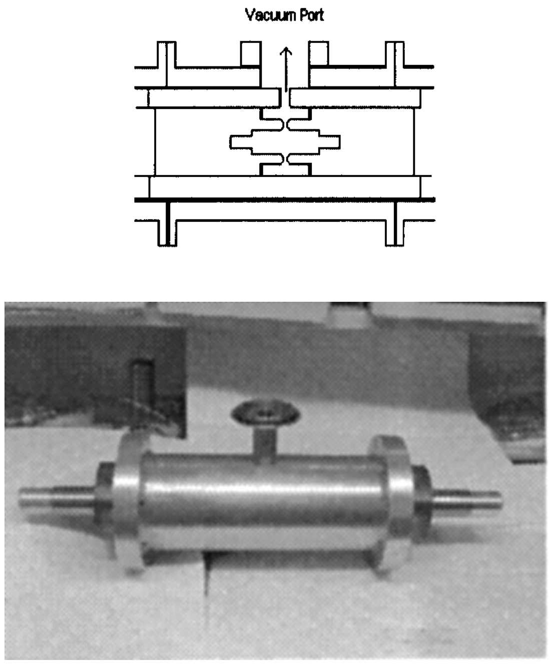

Figure 2. Schematic and photograph of the Experimental Vacuum Peaking Switch.

III. RESULTS

For the 1.27-mm gap separation, incident and transmitted pulses show very little variation. Figure 3 shows a typical incident pulse to the 1.27-mm gap separation and Fig. 4 shows the transmitted pulse. Notice in Fig. 3 that there is no reflected pulse, indicating that the pulse is encountering virtually no impedance variation in the line. The response of the pulse to this smallest of gap separations was as if the gap was virtually not there.

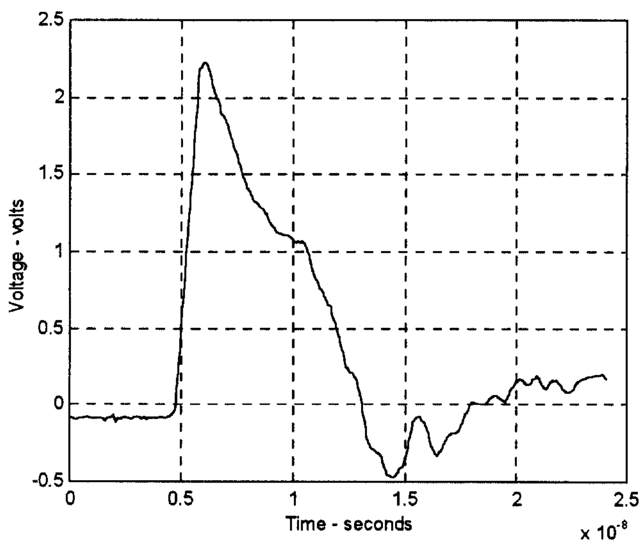

Figure 3. Typical Incident Pulse to 1.27-mm Vacuum Gap

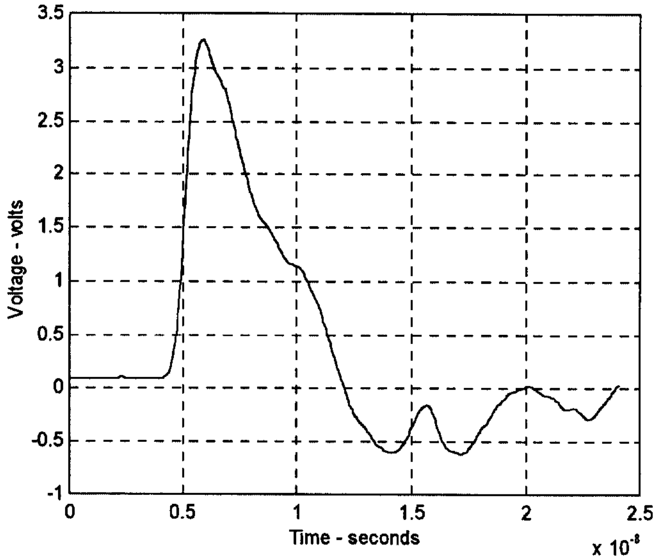

Figure 4. Typical Transmitted Pulse from 1.27-mm Vacuum Gap

For the 2.54-mm gap separation, incident and transmitted pulses show extreme variation. Figure 5 shows a typical incident pulse to the 2.54-mm gap separation and Fig. 6 shows the transmitted pulse. Notice in Fig. 5 that there is a reflected pulse, indicating that the pulse is encountering the vacuum gap now as an impedance variation in the line. The response of the pulse to this gap separation is significant. After an initial increase in rise time and subsequent voltage dip, the transmitted pulse becomes very flat at later times. The rise time is improved in this case from 700 ps for the incident pulse to 400 ps in the transmitted.

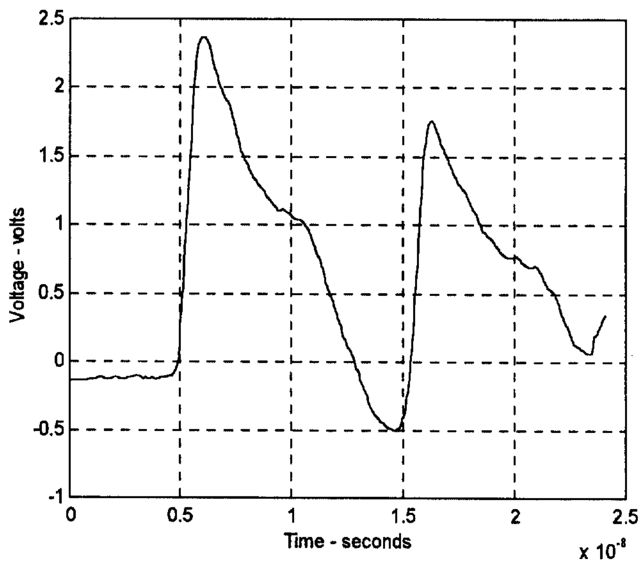

Figure 5. Typical Incident Pulse to 2.45-mm Vacuum Gap

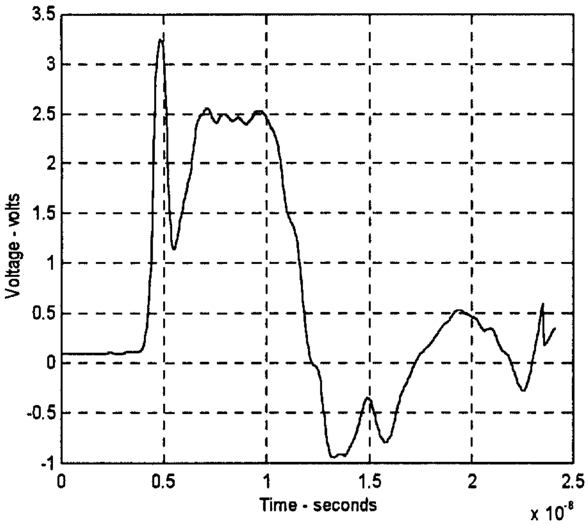

Figure 6. Typical Transmitted Pulse from 2.54-mm Vacuum Gap

For the 5.08-mm gap separation, incident and transmitted pulses again show extreme variation. Figure 7 shows a typical incident pulse to the 5.08-mm gap separation and Fig. 8 shows the transmitted pulse. Notice in Fig. 7 that there is again a reflected pulse, indicating that the pulse is encountering the vacuum gap as an impedance variation in the line. The response of the pulse to this gap separation is once again significant but now different from both preceding cases. After an initial increase in rise time, the pulse is dramatically shortened. The rise time is improved in this case from 1 ns for the incident pulse to 300 ps in the transmitted.

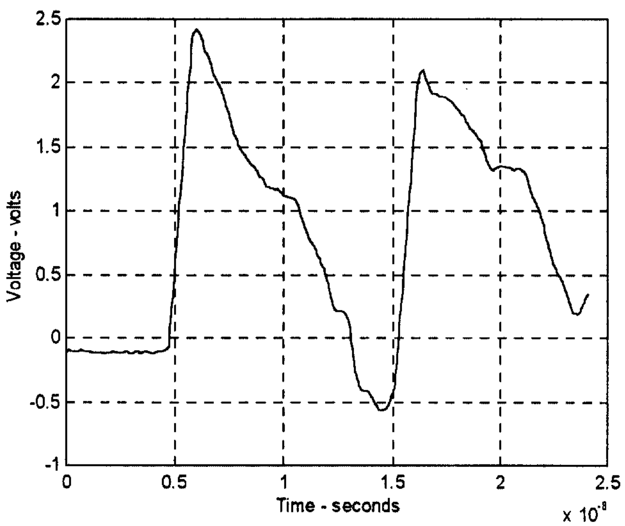

Figure 7. Typical Incident Pulse to 5.08-mm Vacuum Gap

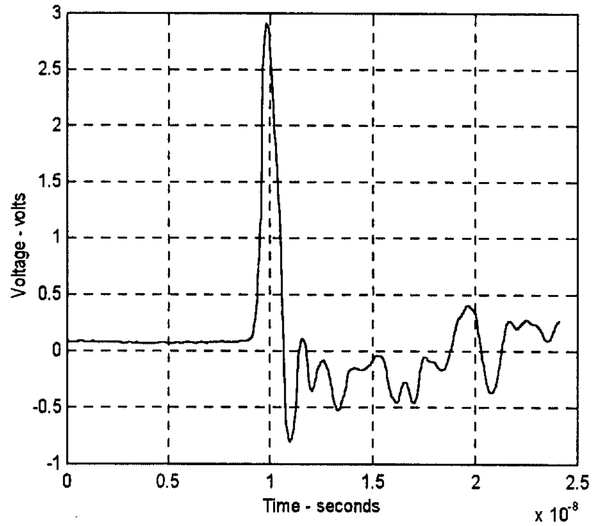

Figure 8. Typical Transmitted Pulse from 5.08-mm Vacuum Gap

IV. CONCLUSIONS

This work strongly suggests that vacuum gap switches could have great utility as peaking switches for extremely high voltage pulsers in the nanosecond and subnanosecond regime. This preliminary work shows that these gaps can improve rise time and greatly alter pulse shape with simple variations in gap length. The performance of these gaps is of particular interest due to the ease and safety of their use in comparison to high-pressure, hydrogen filled peaking switches.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

[1] N. Shimomura, et al., “Electrical Breakdown of Hydrogen and Helium on Subnanosecond Time Scales,” to be submitted to Transactions on Plasma Science.

[2] D. W. Scholfield, et al., "Investigation of the Paschen Curve of Nitrogen via the Application of Nanosecond Pulsed Electromagnetic Radiation," Journal of Applied Physics, Vol. 76, No. 3, p. 1473, August 1994.